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THE LOCAL SUPERGALAXY AS THE STRUCTURED ASPECT OF A UNIVERSAL BACKGROUND OF X-RAYS

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ABSTRACT

It is shown that Silk's model for a universal X-ray background leads to a measurable structure arising from the local supergalaxy. A telescope tuned for detecting this structure would have a field of view $\gtrsim$1 arc degree with a resolution $\lesssim$10 arc minutes. The ratio of the expected signal to the observed diffuse background is of the order of unity.

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An important application for an X-ray telescope[1,2] with a resolution of $\lesssim$10 arc minutes is the measurement of the fine structure characteristic of a universal background. Silk[3] attributes the observed background to the superposed contributions from all normal galaxies. The following discussion describes how this model leads to a measurable structure.

Definitions:

$I \equiv$ observed diffuse background flux (ergs/cm^2-sec-sr)

$\phi \equiv$ half-angle subtended by an average galaxy

$\alpha \equiv$ half-angle for the average field of view required to observe one galaxy

$r \equiv$ average galactic radius

$q \equiv$ X-ray power output for an average galaxy (ergs/sec)

For the situation where the observed background is the superposition of the contributions from all galaxies, it is expected that

$$I(\pi\alpha^2) = \frac{q\phi^2}{4\pi r^2} . \tag{1}$$

The observed[4,5] X-ray background flux is

$$I = 9 \times 10^{-8} \text{ ergs/cm}^2\text{-sec-sr} . \tag{2}$$

Silk[3] estimates that the X-ray power output from our own galaxy is

$$q \simeq 10^{39} \text{ ergs/sec} . \tag{3}$$

Insertion of I and q, as given by (2) and (3), into Equation (1) yields

$$\frac{\phi}{\alpha} = 6 \times 10^{-23} r . \tag{4}$$

For $r \sim 3 \times 10^{22}$ cm., this Equation (4) indicates that ϕ and α are of the same order. Hence, for the $\sim 10^{10}$ galaxies of the metagalaxy[6,7]

$$\pi\phi^2 \simeq \pi\alpha^2 = 4\pi/10^{10}$$

$$\rightarrow \phi \simeq 4 \text{ arc seconds} . \tag{5}$$

This angular size ($\phi \simeq 4$ arc seconds) for an object of radius equal to that of our galaxy ($r \sim 3 \times 10^{22}$ cm) would correspond to a distance of $\sim 2 \times 10^{27}$ cm., comparable to the radius (R) of the metagalaxy. The fineness of this structure ($\phi \simeq 4$ arc seconds) would be difficult to detect.

The situation for the local supergalaxy[7] of $\sim 10^4$ galaxies is promising as regards detectable structure. The radius (R′) of the local supergalaxy is $R' \sim 2 \times 10^{25}$ cm. Therefore, the half-angle ϕ' subtended by a representative galaxy would be

$$\phi' = \frac{r}{R'}$$

$$\rightarrow \phi' \simeq 5 \text{ arc minutes} . \tag{6}$$

The half-angle (α') for the average field of view required to observe one such galaxy is given by

$$\pi(\alpha')^2 = 4\pi/10^4$$

$$\rightarrow \alpha' \simeq 1 \text{ degree} . \qquad (7)$$

Over a field of view for which $\alpha' \sim 1$ degree, it is expected that the average background (2) is achieved, corresponding to $\sim 9 \times 10^{-8}$ ergs/cm^2-sec-sr. However, over the ~ 5 arc minutes half-angle subtended by a representitive galaxy of the local supergalaxy it is expected that the background increases by an amount

$$\Delta I \simeq \frac{q}{(2\pi r)^2} = 3 \times 10^{-8} \text{ ergs/cm}^2\text{-sec-sr} , \qquad (8)$$

for $q = 10^{39}$ ergs/sec and $r \simeq 3 \times 10^{22}$ cm.

Comparing (8) with (2), it is important to note that ΔI is comparable to I.

The flux (J) from a representative galaxy of the local supergalaxy is given by

$$J = (\Delta I)\left(\pi \phi'^2\right)$$

$$\rightarrow J \simeq 2 \times 10^{-13} \text{ ergs/cm}^2\text{-sec.} \qquad (9)$$

For a spectrum of the form given by Seward et al.[4] for photons $\gtrsim 4$ keV, this energy flux (9) corresponds to $\sim 2 \times 10^{-5}$ photons/cm^2-sec.

In summary, the galaxies of the local supergalaxy are expected to give a significant structure to the X-ray background, with the following features:

i) The deviation in the flux is comparable to the general sky background.

ii) The enhanced flux is associated with angular regions $\sim$5 arc minutes, half-angle.

iii) The average field of view required to observe one such enhanced region is $\sim$1 degree half-angle.

iv) The photon flux ($\gtrsim$4 keV) anticipated from a representative galaxy of the local supergalaxy is $\sim 2 \times 10^{-5}$ photons/cm^2-sec.

REFERENCES

1. Giacconi, R. and Rossi B., J. Geophys. Res. 65, 773 (1960).

2. Giacconi, R., Harmon, N. F., Lacey, R. F., and Szilagyi, Z., NASA Contractor Report NASA CR-41 (1965).

3. Silk, J., submitted to the Astrophysical Journal, August 2, 1967. American Science and Engineering, Inc., Publication ASE-1697.

4. Seward, F. D., Chadil, G., Mark, H., Swift, C., and Toor, A., Ap. J. 1967 (in the press).

5. Byram, E. T., Chubb, T. A., and Friedman, H., Science 152, 66 (1966).

6. Allen, C. W., Astrophysical Quantities, University of London (Athlone Press) 1955.

7. Ginzburg, V. L., and Syrovàtskii, S. I., The Origin of Cosmic Rays, Pergamon Press (Oxford) 1964.